Zooming into the Stem Pipeline: Post-Secondary Participation and Attrition in Mathematics

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Abstract: This paper presents results from research that investigated the participation and attrition rate of male and female candidates in two post-secondary mathematics courses (Pure Mathematics and Applied Mathematics). The data for this study consisted of the course results over five years from 2013–2017 for 15,220 candidates (N = 19,585) from 71 post-secondary educational institutions in Jamaica. They were analysed using frequencies (totals and percentages) and descriptive statistics. The data analysis revealed that, on average, over the five years and across each of the five years, approximately 18% of the students who engaged in post-secondary education opted to participate in a mathematics course. However, there was a sharp decrease in the Year 2 student participation after completing the related Year 1 course. Another key finding was that a higher percentage of males chose to undertake Applied Mathematics in Year 2 and equal proportions of male and female candidates in the other three courses. These findings suggest that initiatives are needed which improve student achievement and experience in the first year of each mathematics course which could potentially decrease student attrition across years and curb the leakage at this juncture of the STEM pipeline.

Keywords: Post-secondary, Mathematics, Participation, Attrition, Gender

Citation: George, L. (2023). Zooming into the Stem Pipeline: Post-Secondary Participation and Attrition in Mathematics. In M. Shelley, O. T. Ozturk, & M. L. Ciddi, *Proceedings of ICEMST 2023-- International Conference on Education in Mathematics, Science and Technology* (pp. 249-258), Cappadocia, Turkiye. ISTES Organization.

Introduction

In today's rapidly evolving world, there is an ever-increasing demand for graduates with skills and qualifications in Science, Technology, Engineering, and Mathematics (STEM) disciplines (Murcia et al., 2020). These fields are critical in driving innovation, economic growth and addressing complex global challenges (Waite & McDonald, 2019). However, despite the growing demand, the number of individuals with STEM qualifications is still well below what is needed (Falco, 2017).

The STEM pipeline is a metaphor that was developed to depict the academic and career pathways individuals follow in STEM fields. It encompasses various educational levels starting from early childhood to primary, secondary, and post-secondary levels, then higher education and into STEM careers. One characteristic of this

pipeline that has gained prominence over the past two decades is its porousness. Across successive educational levels, there appears to be a notable decrease in the number of individuals, especially women, enrolled in STEM courses (Clark Blickenstaff, 2005). One way to tackle this problem could involve boosting the number of students who complete STEM courses at different junctures along the STEM pipeline, especially where participation in these courses is optional (DeCoito, 2016; Dooley et al., 2017). The research reported in this paper focuses on the post-secondary level, which is the educational stage following compulsory high school education but preceding university. This part of the STEM pipeline has received limited scholastic attention (Rigby, 2017). This study also centres on mathematics, a key subject within STEM education (National Research Council, 2011). It aims to address the following research questions:

1. How does the candidate's participation in two post-secondary mathematics courses compare in general and by gender?
2. What is the attrition rate in general and by gender for each post-secondary mathematics course from Years 1 to 2?

Research Context

This research was undertaken in Jamaica. In this country, the post-secondary level consists of two years of study. Students who choose to pursue mathematics at this stage primarily select to complete Pure Mathematics and/or Applied Mathematics. Students take Unit 1 of the course in their first year and the second unit in their final year. Each unit comprises three modules (see Table 1).

Table 1. Pure and Applied Mathematics Content

Course	Year	Units	Module		
			1	2	3
Applied Mathematics	1	Statistical analysis	Collecting and describing data	Managing uncertainty	Analysing and interpreting data
	2	Mathematical applications	Discrete mathematics	Probability and distributions	Particle mechanics
Pure Mathematics	1	Algebra, geometry and calculus	Basic algebra and functions	Trigonometry, geometry and vectors	Calculus I
	2	Complex numbers, analysis and matrices	Complex numbers and calculus II	Sequences, series and approximations	Counting, matrices and differential equations

The mathematics assessment related to the two courses has internal and external components with different weightings. The external component carries the majority weight of 80% and includes two papers. Paper 01 is a compulsory multiple-choice exam worth 30% of the final grade, while Paper 02 consists of six constructed-response items and contributes 50% to the final grade. The internal school-based assessment, worth 20%, is composed of three class tests designed by the teacher and externally reviewed by the examining board.

Review of Related Literature

Post-secondary Participation in Mathematics

Following Noyes (2009), this study defines participation as the successful completion of a course of study and the subsequent undertaking of the associated examination, which may result in either a pass or fail grade. Hodgen et al. (2010) conducted a comparative analysis of post-secondary mathematics participation across 24 countries. Their findings revealed varying levels of participation in mathematics courses among these countries. In eight countries, namely the Czech Republic, Estonia, Finland, Japan, Korea, Russia, Sweden, and Taiwan, the study observed that all students (95-100%) enrolled in at least one mathematics course. This high participation rate suggests that post-secondary mathematics was compulsory in these countries. In six countries, including Canada, France, Germany, Hungary, Ireland, the USA (specifically Massachusetts), the majority of students (81-94%) engaged with mathematics courses. Four countries, namely Australia (specifically NSW), the Netherlands, New Zealand, and Singapore, reported a participation rate ranging from 51% to 80%. The participation rate in Hong Kong, Spain, and Scotland varied from 21% to 50%. Finally, in three countries, England, Wales, and Northern Ireland, only 20% of post-secondary students or fewer pursued mathematics. Hodgen et al. (2010) lamented that this participation rate was relatively low and warranted Government intervention related to policy, curricula and practice to improve it.

As it relates to gendered participation, studies conducted in various regions worldwide, including the United States, Canada, Australia, Europe, and Africa, consistently reported a gender disparity in the selection of post-secondary mathematics courses (Finnie & Childs, 2018; Hill et al., 2010; Huggins & Randell, 2007; Matthews & Pepper, 2007; Mendick, 2005; Noyes, 2009; Schneider et al., 2015). The research findings indicate that more males tend to choose these courses than females. Additionally, at this level, males generally outperform females (Boaler, Altendorff, & Kent, 2011; Noyes, 2009), even when both genders' high school mathematics achievement is similar (Boaler et al., 2011). However, a limited number of studies, such as the US and Canadian samples in Watt et al. (2006) and Card and Payne (2015), respectively, report that males do not prefer higher levels of mathematics. Mendick (2005) discusses post-secondary participation in the UK and highlights that the greater participation of males in mathematics courses becomes more pronounced as education progresses. O'Dea et al. (2018) conducted a meta-analysis of over 1.6 million students and found that this gender disparity persists "despite girls outperforming boys at school in the relevant subjects" (p. 1).

Attrition in Post-Secondary Mathematics Courses

In England, Mendick (2008) highlights the long-standing issue of a significant number of students failing in the first year of their two-year post-secondary mathematics courses. This high failure rate has consequently led to substantial attrition, resulting in many students dropping out between Year 1 and Year 2. Noyes and Sealey (2012) support these findings and further note that mathematics exhibits one of the highest attrition rates compared to other subjects, although there is notable variation between schools. Their study reports an attrition

rate of 29.4% from Year 1 to Year 2 for their collected data from a specific year. It should be noted that Noyes and Sealey (2012) were unable to determine if this dropout rate extended beyond their sample; nevertheless, they concluded that there is indeed a significant problem with Year 1 dropout in mathematics.

Method

This research examined Jamaican students' post-secondary mathematics participation data from 2013 to 2017. The examination board responsible for administering these examinations provided the research data. The sample for this study consisted of candidates from 71 educational institutions, totalling 15,220 candidates, with 7,896 females and 7,324 males. For Year 1 Pure Mathematics, 71 schools provided the data, while 64 schools for Year 2. For Applied Mathematics Years 1 and 2, the sample comprised 16 and 17 schools, respectively.

The examination board administers the mathematics examinations twice a year. However, most post-secondary school students complete their exams in May/June. Therefore, the data analysis focused on this specific period. Frequencies (totals and percentages), means, and standard deviations were calculated using EXCEL 2016 and SPSS 21 to address the research questions.

Results

Research Question 1: How does the candidate's participation in two post-secondary mathematics courses compare in general and by gender?

Across the five years, there was very little change in the general and gendered percentage of candidates participating in the mathematics courses. For the present sample, the proportion of students who completed post-secondary mathematics courses for 2013-2017 was as follows: 19.9, 18.6, 17.6, 17.4, 18.2, with approximately a 1:1 female-to-male ratio (see Table 2).

Table 2. Post-secondary Mathematics Participation

Participation	2013	2014	2015	2016	2017	Average
No. of candidates who do post-secondary courses	14,758	15,811	16,703	16,887	16,117	16,055
No. of candidates who complete a post-secondary mathematics course	2,935	3,021	3,214	3,409	2,641	3,044
% of candidates who complete a post-secondary mathematics course	19.9	18.6	17.6	17.4	18.2	18.3
% of females who complete a post-secondary mathematics course	10.7	10.2	9.7	10.4	8.3	9.8

Participation	2013	2014	2015	2016	2017	Average
% of males who complete a post-secondary mathematics course	9.2	8.9	9.6	9.8	8.1	9.1

Table 3 presents the overall gendered participation as per the two mathematics courses, Pure Mathematics and Applied Mathematics. A comparison of the candidate participation by course and year shows that from 2013–2017, approximately 62% of the students selected Pure Mathematics compared to only 4% for Applied Mathematics. In Year 2, the percentages were about 32% for Pure Mathematics and 1% for Applied Mathematics. The post-secondary student participation in Applied Mathematics is significantly lower compared to Pure Mathematics, even among schools offering both subjects.

Another significant finding was the differential enrollment patterns between male and female candidates in the different mathematics courses. Specifically, a higher percentage of male students chose to undertake Applied Mathematics Year 2 than their female counterparts. This suggests a potential gender disparity in selecting advanced mathematics courses, with males showing a stronger inclination towards Applied Mathematics. On the other hand, the enrollment proportions of male and female candidates were relatively equal in the other three courses.

Table 3. Mathematics Participation per Course and Gender

Course	Gender	
	F (No., %)	M (No., %)
Applied Mathematics Year 1	329 (50.69)	320 (49.31)
Applied Mathematics Year 2	88 (40.93)	127 (59.07)
Pure Mathematics Year 1	4,875 (51.74)	4,548 (48.26)
Pure Mathematics Year 2	2,604 (52.79)	2,329 (47.21)
Total	7,896 (51.88)	7,324 (48.12)

Research Question 2: What is the attrition rate in general and by gender for each post-secondary mathematics course from Years 1 to 2?

In the case of Applied Mathematics, the participation rate for Year 2 from 2013 to 2017 was approximately one-third of the Year 1 participation. As for Pure Mathematics Year 2, the participation rate was about 50% lower than that of Year 1. Furthermore, the attrition rate in Applied Mathematics is higher for females than males, while in Pure Mathematics, the attrition rate between genders is nearly equal.

This research found that over the five-year period, from 2013-2017, the average attrition rate from Year 1 to Year 2 for Pure Mathematics, for males and females, was 50% and 48%, respectively. For Applied Mathematics, males recorded an attrition rate of 60% and females 72% by gender. These results demonstrate a substantial decrease in student participation in Year 2 courses of Applied and Pure Mathematics following the completion of Year 1. It indicates that many students who initially enrolled in mathematics courses did not progress to the advanced level.

Discussion

This research found that approximately 18.3% of students participating in post-secondary education administered by the CXC examining board opted to complete a mathematics course. This rate is low compared to international participation rates reported by Hodgen et al. (2010). Similar to the three counties, England, Wales, and Northern Ireland, that reported comparable participation rates of 20% or fewer, post-secondary mathematics participation in Jamaica is optional for students. Hodgen et al. (2010) pointed out that the issue of choice appeared to be a significant factor affecting mathematics participation rates after high school. Furthermore, Noyes and Adkins (2017) posit that end-of-high school mathematics achievement is the main contributor to post-secondary mathematics participation. This assertion may apply in the Jamaican context, where approximately half of the cohort sitting exit mathematics examinations at the end of high school do not obtain a passing grade (George, 2022). This low pass rate suggests that many students have considerable difficulty learning mathematics, so they would not be likely to continue engaging with the subject when it is no longer compulsory. The high-stakes end-of-high school mathematics examination is a requirement for students who wish to pursue further mathematics education beyond high school. The low number of students passing the mathematics examinations greatly diminishes the pool of potential candidates for post-secondary mathematics courses. Additionally, many students have a negative attitude towards and fear mathematics (Bourne, 2019; Ministry of Education, 2013). These factors, as proposed by Matthews and Pepper (2007), contribute to students' experiences with mathematics and can significantly impact their participation in post-secondary education.

The completion rates of the two post-secondary mathematics courses for males and females were nearly equal. This finding contrasts with the majority of global studies that report higher male participation in post-secondary mathematics courses (Hill et al., 2010; Matthews & Pepper, 2007; Noyes & Adkins, 2016; O'Dea et al., 2018; Schneider et al., 2015; Smith & Golding, 2018). This finding is significant as it presents a departure from global trends observed in the empirical literature, offering an example of the unique characteristics of Caribbean cohorts. Furthermore, it is noteworthy because it suggests a level of gendered participation equity that aligns with the goals pursued by international educational organisations (Smith & Golding, 2018; UNESCO, 2010, 2017).

This study also found a marked decline in the number of students who participated in Year 2 for Pure and

Applied Mathematics courses after completing the corresponding Year 1 course. This finding aligns with research conducted in the UK regarding mathematics participation during the post-16 stage (Mendick, 2005; Smith & Golding, 2017). While this consistency with previous research is notable, the author suggests that various factors, including students' career aspirations and experiences during the course, may influence this observation. Additionally, the quality of the grades obtained in Year 1 courses may play a crucial role. These grades could determine students' eligibility to progress to Year 2 or may impact their self-efficacy and confidence in pursuing more advanced related courses. Mathematics learning is hierarchical and cumulative in that new knowledge builds on existing knowledge (Babtie & Emerson, 2015). Previous mathematics achievement has been found to be predictive of future performance (Card & Payne, 2015). Therefore, a weak grade in Year 1 may indicate a limited understanding of mathematical concepts, which can potentially hinder performance in subsequent related courses. Future research endeavours could investigate the underlying reasons for the observed attrition, providing valuable insights into the phenomenon.

Conclusion

This research examined the gendered mathematics participation and attrition of students at the post-secondary educational level. Investigating participation and attrition rates at this level is crucial for addressing the decline in student engagement in STEM courses as they progress through the STEM pipeline across educational levels. Such research provides valuable insights into the current situation within different jurisdictions, helping to identify potential barriers and disparities. It also informs targeted interventions and strategies that promote equity, diversity, and inclusion in STEM education. Finally, it adds to the existing body of knowledge on the topic, expanding the international portrait of what is known in the research domain.

The outcomes of this research hold the potential to shape policy and educational initiatives aimed at enhancing the representation and retention of students, particularly female students, in post-secondary mathematics courses. By creating a supportive and inclusive learning environment, educational institutions can better equip their students with the necessary skills and knowledge to thrive in STEM fields and meet the evolving demands of the world.

Recommendations

Based on the research findings, this paper presents five recommendations, which are as follows:

1. Implement policy and practice measures to enhance mathematics achievement at the end of high school.
2. Provide increased support to Year 1 students enrolled in post-secondary mathematics courses to enhance their performance.
3. Enhance the experiences and engagement of Year 1 students in mathematics courses, which may

involve organising professional development sessions for teachers.

4. Develop policies specifically targeting post-secondary mathematics participation, outlining specific initiatives to be implemented in order to improve participation rates.
5. Regularly monitor post-secondary participation and attrition in mathematics courses and utilise these data to guide future actions.

Acknowledgements

The author is grateful to the Caribbean Examinations Council for providing the data for this research.

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